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OF THE IMPROVED
REFLECTING and REFRACTING
TELESCOPES,
AND
SCALE for SURVEYING, &c.

BRITISH MUSEUM

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DESCRIPTION, &c.

THE REFLECTING TELESCOPE.

AN opening is made in the eye-piece, more than half round, parallel to its ends, and in the focus of the eye-glaſs. On the eye-piece, a cylindrical tube is ſo fitted to its ſurface, as to be turned round with eaſe. Into the eye-piece, and under the ſaid opening, is placed a ſhort cell, having two pins, with fine ſharp points. This cell is ſo faſtened to the inſide of the cylindrical tube, that the points may always move in the focus of the eye-glaſs, by means of an adjuſting ſcrew. It is alſo furniſhed with the neceſſary apparatus for giving it a free, eaſy, and uniform motion, both horizontally and vertically, and mounted on an accurate theodolite, with a Nonius diviſion, which latter addition is neceſſary for land-ſurveyors.

THE SCALE.

THE Scale *, ſuch as fig. 1. being deſigned for land meaſure, is conſtructed upon optical principles, adapted to the teleſcope, and divided into Gunter's chains by the numbers 1, 2, 3, 4, &c. the ſpace of one chain being prefixed, and divided into 100 links, by 4 ſlanting lines. The number of links is denoted by 4 parallel lines, dividing the breadth of the ſcale into 5 equal parts; each diviſion is 5 links; and the numbers 25, 50, 75, are placed to help the obſerver to determine more ſpeedily.

A ſcale, conſtructed as fig. 1. will be of ſufficient length for moſt purpoſes in ſurveying; as any viſible right line, not exceeding a quarter of a mile, may be determined within 2 inches; the ſcale being placed at one end, perpendicular thereto, and the teleſcope at the other. The obſerver, at the teleſcope, takes the length of the line in chains and links, by applying the points in the focus of the eye-glaſs to the image of the ſcale, in the ſame manner as he would apply the points of a pair of dividers to a common ſcale, to obtain the length of any line comprehended between them.

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* It is graduated upon a piece of board, about 8 feet in length, 4 inches in breadth, and 1 inch in thickneſs; and may be divided ſo as to expreſs the diſtance in feet, yards, or any other denomination. The board is cut in 2 parts, and made to ſhut together with a hinge, and thereby rendered more portable. The ſcale may be ſet perpendicular to the required line, by means of a ſmall tube with croſs hairs placed at the end of it.

THE REFRACTING TELESCOPE.

FOR the Refracting Teleſcope, the neceſſary apparatus before deſcribed is requiſite; and the two fine points * are fixed exactly in the focus of the eye-glaſs, horizontally; which may be adjuſted to the ſcale by turning the ſmall tube which contains the eye-glaſs. The ſcale is conſtructed nearly after the ſame manner with that made for the reflector.

To find the content of a field, with either of theſe inſtruments, let the teleſcope be placed in it, ſo as the obſerver may ſee all its angles from his ſtation; if near the centre the better. The perſon who carries the ſcale is to go all round the field, ſtopping at each angle, and placing the ſcale at right angles to the axis of the teleſcope, as before-mentioned; which may be moved from corner to corner, and from right to left, if required, with the help of a ſignal given by the obſerver to him who carries it. After the diſtances all round the field are taken, and all the angles included betwixt them, with the theodolite, plan it out on a ſheet of paper in the uſual manner; *e. g.* with a Nonius protractor lay off the angles; or from a ſcale of degrees and minutes, with the radius 60 degrees, deſcribe a circle; and on its circumference ſet off all the angles from the ſaid ſcale. Draw lines from the centre of the circle, through each point in its circumference; then ſet off the length of every line, from a ſcale of equal parts, from the centre. Theſe points will give you the limits of the field, which may be laid out in trapeziums, triangles, &c. and meaſured from the ſame ſcale of equal parts, to find the true content of it*.

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* Inſtead of two fine ſteel points, I have ſubſtituted two fine lines cut on glaſs, which anſwer the purpoſe full as well, when placed in the focus of the eye-glaſs.

If the obſerver from his ſtation cannot ſee all the angles of the field, let him meaſure it in two parts, and take two ſtations in the manner above deſcribed.

Thus may the ſurveyor, in leſs than two hours, take all the dimenſions of an irregular polygon, neceſſary for obtaining its area, if it be as much as 80 or 100 acres, and limited by 20 or 30 unequal ſides.

In order to facilitate county ſurveying, by taking diſtances of 6 or 7 miles, a ſcale may be made by placing exactly upright two boards, 6 or 7 feet long, and 5 or 6 inches broad, with their ſides towards the obſerver white. Theſe are the limits of the ſcale, which is always the tangent or ſubtenſe of the ſmall angle; and the line required is always the radius: theſe (the radius and tangent) muſt be therefore placed perpendicular to each other, which is eaſily done by taking the bearing of the line you are meaſuring; and at ſuch diſtance apart as will, as nearly as you can gueſs, correſpond with the required line. The obſerver may give ſignals to the perſon who puts up the marks for the limits of the tangent, to ſet them nearer together or farther apart, until they are right. The ſignals will be ſeen by the perſon at the ſcale, if he has a teleſcope magnifying 14 or 15 times. The length of the ſcale, which for any of theſe diſtances will not be more than 80 or 90 yards, may be meaſured with a portable ſtaff of 5 or 6 yards long.

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* The ſurveyor will diſcover how eaſily the content of the field is found by trigonometrical calculation, ſince by this method there are two ſides of the triangle given, and the angle included betwixt them.

I have found by many trials, that a diſtance of 6 or 7 miles may be fixed within a yard; therefore, if a meridian or long line be meaſured in ſmall portions, ſuch as 5, 6, 7, or 8 miles at a time, the concluſion may be depended upon, and be more accurate than if meaſured by long ſtations of 20 or 25 miles at a time; although I have determined the diſtances of 12 ½, 12 ¾, and 13 miles, to the 12,000th part of their reſpective wholes, when the air was tolerably clear, and when very clear, to the 20,000th part of the whole. For a proof of theſe meaſures, when the points appeared to take in the limits of my ſcale exactly right, if I moved the teleſcope nearer to, or farther from the ſcale, ſo as to make the radius 2 yards leſs or 2 yards more, I could for the moſt part perceive it not to be exactly right. Hence this manner of aſcertaining a diſtance has one excellence above all others, which is, the obſerver may be ſatisfied whether his meaſure be right or wrong, by a ſingle inſpection.

The common method of meaſuring with the chain, &c. beſides the inaccuracies to which it is liable, does only give the length of the ſurface of the ground between two objects, and therefore not the proper diſtance, unleſs the ſurface be ſtraight, and no obſtacles to hinder its being meaſured from one end to the other; how often this is practicable I leave to the conſideration of thoſe who are moſt accuſtomed to meaſure lines; and doubt not but on the whole they will find, that the teleſcopic method has, beſides eaſe, accuracy, and univerſality, neceſſity itſelf to recommend it.

In taking the diſtance to an inviſible object from the point of view, this method has the advantage of all others, in determining the length of the baſe line with ſuch preciſion: of which I ſhall beg leave to give the reader an example. From any part of the line A B, (fig. 2.) as ſuppoſe at F, you want to know the diſtance to an inviſible object at C. Two places muſt be fixt upon, as D and E, from whence you may ſee the object at C: after having with your inſtrument fixt at A, and ſcale at B, determined your baſe line A B, take the angle D A B with your theodolite, remove the inſtrument to B, and take the angle A B E. It muſt be then removed to the two ſtations D and E, from whence the object at C is viſible; and take the

angle

angle A D C at D and the angle B E C at E; you will thereby find the diſtance C F required, when calculated by trigonometry, or planned upon paper, and meaſured by a ſcale of equal parts, as deſcribed p. 8.

The utility of this inſtrument in levelling is obvious, ſince, by a ſmall ſcale graduated, and fixt to the ſtation-ſtaff and teleſcope prepared as before deſcribed, you have at one view the exact diſtance between your ſtation-ſtaff and teleſcope, at the ſame time that you take your level.

In taking the diſtance to inacceſſible objects, as from a ſhip to a fort, from camp to caſtle, &c. this inſtrument will be found of great uſe; as the exact meaſure of the tangent is what is required in order to find the true length of the radius correſponding: therefore the length of any known tangent which the points appear to take in exactly right, will be ſufficient for determining the required diſtance; but as this length cannot be known always, in taking inacceſſible diſtances, let the teleſcope be furniſhed with two fine points placed vertically in the focus of the eye-glaſs, and the upper point be made to approach towards or recede from the other by uſing a micrometer ſcrew. If you are at ſea with your inſtrument, and you would know the diſtance to a fortification; ſuppoſe (as it frequently happens) you diſcover from the ſhip a ſoldier upon duty, move the upper vertical point towards or from the other ſo as to take in the exact height of the ſoldier, which being about 5

feet

feet 8 inches in general, a pretty exact calculation of the diſtance he is from you may be made, as his height decreaſes in the inverſe ratio of the diſtance; and the index of the micrometer ſcrew will ſhew how much the points have been moved from their firſt poſition *, to the 10,000th part of an inch. If a number of ſoldiers can be ſeen from your ſtation, by taking a mean of their different heights, the diſtance may be aſcertained with greater accuracy.

To explain the particular uſes in ſurveying, &c. to which this inſtrument may be applied, would take up too much room for a deſcription of this ſort. I think it however neceſſary to inform the reader, that in taking the ſurveys of woods, coppices, &c. where it will ſometimes happen, that the perſon who carries the ſcale cannot place it exactly horizontal, ſo as the whole of it may be ſeen by the obſerver, with the teleſcope, from his ſtation; in which caſe let it be placed vertically or exactly upright; when the obſerver may, by turning the fixt points in the focus of the eye-glaſs vertically, take the length of the line near enough for common practice; I ſay near enough for common practice, for I have obſerved the horizontal poſition of the ſcale has this advantage, namely, the whole of it being ſeen by the obſerver with the teleſcope,

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* For a calculation of this ſort, it will be neceſſary to obſerve firſt the exact diſtance the points are apart when you view the height of 5 feet 8 inches, at a known diſtance, with the teleſcope.

through the ſame medium of air, which is well known to differ in denſity at different diſtances, from the ſurface of the earth, conſequently the length of the line cannot be ſo accurately taken when the ſcale is placed exactly upright.

The accuracy of this method of meaſuring exceeds what I could reaſonably expect by calculations deduced from the theory. Several circumſtances much in its favour are inſeparable from it. The obſerver's ſtation is the centre of a circle, whoſe radius is the diſtance required; and is obtained by meaſuring the length of a ſcale, that is the tangent or ſubtenſe of the ſmall arc; whoſe limits are defined by viewing their image in the focus of a teleſcope, between two points there placed, and moving them up and down till they appear to touch the very extremities of the ſaid limits moſt exactly. The manner of ſeeing is natural, and by much practice will certainly become habitual; and therefore the determination thereby continually approach nearer and nearer to perfection.

An experiment for determining the quantity of a ſmall angle.

I cauſed two right lines, nearly a foot long each, to be drawn on a plane, the diſtance between them at one end 8,25 inches, at the other 8,24 inches; theſe were placed perpendicular to the axis of my teleſcope, at the diſtance of 23415,48 inches; whence it is eaſy to compute that the diſtance of the lines at the wideſt end, is

equal

equal to the tangent of 72,673 ſeconds; at the narroweſt, 75,585 ſeconds; and their difference ,088, which is leſs than the 10th part of a ſecond.

Theſe being placed as above, I viewed them with my Refracting Teleſcope, whoſe focal length is 36,4 inches, and could plainly perceive by the points, at which end they converged; but knowing that prejudice might bias my imagination, eſpecially where ſuch nice determination is required, I deſired a perſon who had a good eye to examine them; he told me the lines appeared neareſt together at the lower part of the plane; which was really the caſe: he then viewed them again ſeveral times, to be thoroughly ſatisfied. I (unknown to him) the next day inverted the plane, and deſired him again to view and examine them; he returned with ſurpriſe, and told me they appeared neareſt together at the upper part of the plane, contrary to what they did the preceding day *. I therefore conclude, from this and many other impartial trials, that the quantity of a ſmall angle may be determined with this inſtrument to leſs than the 10th part of a ſecond.

For taking a ſmall angle in the Heavens, or the apparent diameter of the Heavenly bodies.

Let the teleſcope be furniſhed with a micrometer, placed in the focus of the eye-glaſs, whoſe oppoſite ſides *a c* and *b d* (fig. 3.) may have each 4 fine points at all times exactly facing each other; let the ſide *a c* be made to approach towards, or recede from *b d*, by being cauſed to ſlide between two fixt planes E F and E F, ſo exactly parallel, that the diſtance between each oppoſite point may be the ſame; and to prove that they are ſo, they muſt be tried by the ſcale, at every diſtance of the ſlide between E and F, and altered and adjuſted until they move always parallel, and the diſtance between the oppoſite points be the ſame, to the 50,000th part of an inch. By a calculation made from the before-mentioned trial, it is eaſy to conceive, that if the points deviate ſo much as the 50,000th part of an inch, from being of equal diſtance, it may be perceived.

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* It is to be obſerved, that this experiment was made when the air was very cl

The teleſcope being well adapted for purſuing any planet, &c. whoſe apparent diameter is required—and its focus furniſhed with ſuch a kind of micrometer as I have juſt deſcribed—move the ſliding part *a c* till the image of the ſtar, &c. appears to touch with its two oppoſite extremities any two oppoſite points in the field of the teleſcope. In order to be certain whether or no the extremities of the required diameter do exactly touch, cauſe the image of the ſaid diameter to paſs through the field between, and parallel to the points. During its paſſage, obſerve that it juſt touches at *a*; then, by a quick tranſition of the eye to *b*, obſerve whether the oppoſite point touches when arrived there; then moving the eye to *c*, obſerve whether the ſame that touched at *a* touches again at *c*; thence traverſing

verſing to *d*, obſerve whether the ſame touches here that touched at *b*, and in the ſame manner; and if ſo, one may conclude that the apparent image of the required diameter is taken exactly; but if not, begin at *a* again, repeating the ſame till it exactly fits every where. The time of the image's paſſing between the points (if the magnifying power of the teleſcope be great) need not be more than a minute.

I am not inſenſible that various micrometers have been contrived lately to anſwer the above-mentioned purpoſe with great accuracy; and venture to give the reader a deſcription of this, as it is of the ſame kind with that I uſe for meaſuring the diſtance between terreſtrial objects.——In taking the apparent diameters of the Sun, Moon, and Jupiter, with this micrometer, ten times, one after the other immediately, the difference was not ſo much as the 10th part of a ſecond, when the air was of the ſame denſity; as I apprehend the ſeeming dilatation and contraction of the ſun, which I have obſerved, is partly, if not wholly owing to his being ſeen through a more rare or denſe medium. In the leſſer heavenly bodies, indeed, I believe this is rarely perceived by the beſt micrometers now in uſe.

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F I N I S.

Fig. 3.

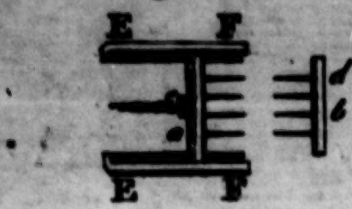

Fig. 2.

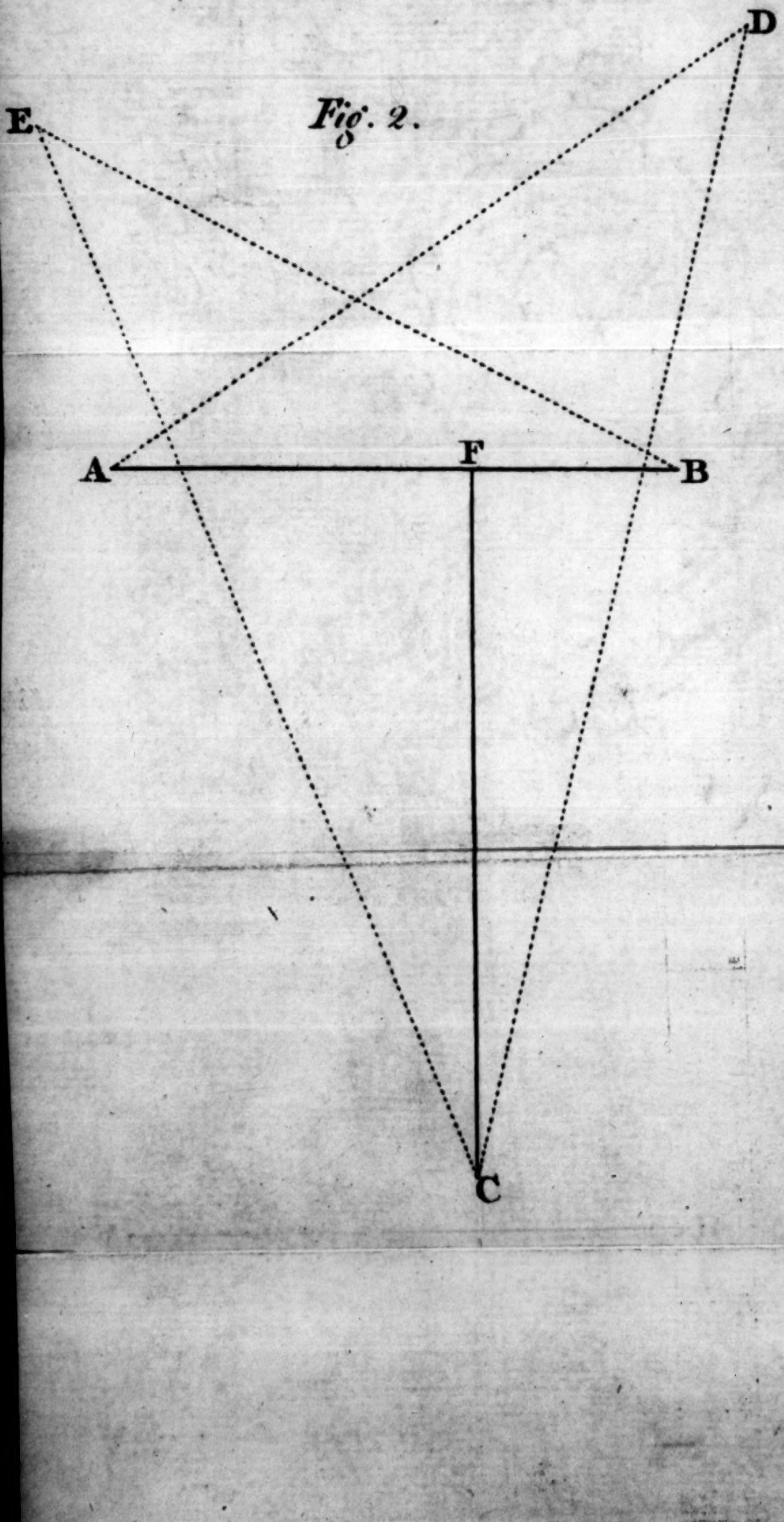

Fig. 1.